

Cosmic Chemistry: Cosmogony

A Spongy Universe

STUDENT TEXT

One of the basic precepts of the standard cosmological model is that the **universe** is **isotropic** and **homogenous**. If it is isotropic, then regardless of the direction in which we look, the universe should look the same. If it homogenous, then we should be able to take astronomical pictures of equal volumes of different large regions of the universe and find a similar mix of galaxies and space no matter where you look.

When astronomers view the night sky, do they see a universe that is isotropic and homogenous? Not really. Nearly all the luminous matter (matter that is seen) in the universe is contained in **superclusters** of galaxies. These superclusters are like long strings on which clusters of galaxies are strung like pearls on a necklace. Superclusters are typically about one hundred million light-years in diameter and contain tens of thousands of galaxies. When we look at the night sky with the unaided eye, we mostly see stars in our galaxy, the Milky Way. Superclusters are made of many clusters of which the local group containing the Milky Way is just one.

A **galaxy** is a large aggregation of stars, bound together by gravitational force. There are three major classifications of galaxies—spiral, elliptical, and irregular. Galaxies are not randomly distributed in space, but are usually grouped together in what are called **galactic clusters**: structures in which a large number of galaxies are found in close proximity to each other. Over half of all galaxies are associated with clusters of various sizes.

Our sun belongs to a spiral galaxy, the Milky Way, which is part of a cluster called “the Local Group.” The Milky Way and Andromeda galaxies appear to be the gravitational anchors of the cluster that drag at least twenty other smaller galaxies along with them. This cluster is not very large, being only about 3 million **light-years** across. Some larger clusters have many thousands of galaxies in them.

The spaces between superclusters are called **voids**, because they are relatively free of **luminous matter**; that is, they contain few, if any galaxies. Voids were not discovered until 1981. All our cosmic observations to that time were two-dimensional, so light coming from stars and galaxies farther away than the voids appeared as bright spots in the voids.

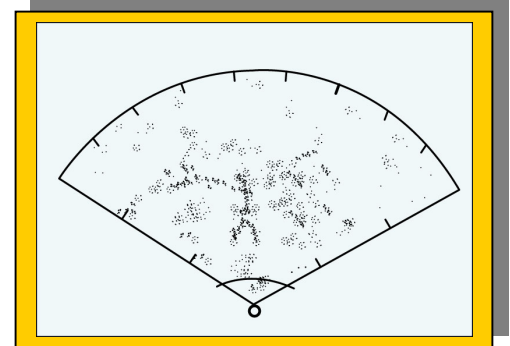
A team of astronomers from the University of Michigan discovered the largest void in the Boötes cluster by doing a very detailed **redshift** survey of a very small region instead of using a full-sky map (see [Student Text, “Doppler Effect—Are You Coming Or Going?”](#)). The “bubble” in Boötes is about 250 million light-years across and appears to contain no normal galaxies whatever. One might expect to find more than 10 thousand galaxies in a volume that size, since the average distance between galaxies elsewhere in the universe is a few million light-years.

The Boötes void was considered just a chance event until another group of astronomers at the Harvard-Smithsonian Center for Astrophysics in Cambridge, MA, announced in 1985 that they had “punched a hole in the sky” in a completely different direction from the Michigan group—and they had found that the universe was full of large bubbles. Cosmologists now refer to these voids as “Hubble bubbles,” in honor of Edwin Hubble, an early pioneer in the exploration of the universe.



Spiral galaxy

Figure 1





The map sketched by the Cambridge group, shown in Figure 1, where the Earth is at the point of wedge and the distance from the Earth increases as one moves away from the point, was again based on a three-dimensional, deep redshift technique. This slice through a piece of the universe so much resembled a cross-section of a sponge that James Trefil describes our universe as “The Spongy Universe.” He says that the solid matter in the universe looks like what you would get if you sliced through a sponge. This solid matter is arranged in an interconnected, stringy network interspersed with large bubbles in which very little, if any, matter is seen.



Description vs. Explanation

In the “Spongy Universe” activity you modeled what astronomers and cosmologists do as they study the universe. First you described the structure of the sponge you were observing and then you developed some explanations as to how those structures were formed. Which was the more difficult, description or explanation?

Describing the structures in the universe is not so easily done as describing a sponge, but it is becoming easier with the development of instrumentation to observe vast areas of the universe. Explaining how the cosmic structures were formed, however, and why matter is clumped on a large scale in the universe, leaving voids or “bubbles” that appear to be empty is much more difficult than explaining how a sponge was formed.

How and when did the “spongy universe” form?

There are two general classes of answers to this question—those that involve events that happened fairly late in the history of the universe, and those that involve the survival of structures formed during the first fraction of a second of the universe.

According to Trefil, if the voids and structures formed late in history, it is not too surprising that the universe should resemble “Swiss cheese.” He reminds us that you cannot make a pile of dirt without digging a hole. If you have regions where galaxies cluster, you might expect to have regions where they are rare. The question then becomes, “what dug the holes?” Could an explosion in space have caused the voids? Or could the bubbles have been formed when several smaller bubbles came together?



If mass was not uniformly distributed in space from the start, but showed a “Swiss-cheese” structure long before the galaxies condensed out of the primordial gas, then solid structures may have formed around the edges of the bubbles, but not in the voids themselves. According to this theory, galaxies may have formed from cosmic strings—long, very dense structures (orderly arrangement of clusters or superclusters)—and the spaces between the strands became the voids.

Needless to say, “Hubble bubbles” are a hot topic in today’s cosmology. Ideas about their origins form are at the frontiers of science.

How can a “spongy universe” be “isotropic and homogeneous?”

How can the universe resemble a sponge and, at the same time, be “isotropic and homogeneous,” as the standard cosmological model maintains? You may have already found a partial answer to that question for yourself as you completed this activity.

When you observed the sponge “up close and personal,” you could see the structures and voids very clearly. But what happened to the detailed structure as your partner moved the sponge farther and farther from you? Eventually, the sponge **appeared** to have the same properties throughout. Does the **distance** at which you observe the sample make a difference? Cosmologists have found that it does when observing the universe.

They have also found that the **size** of the sample observed is important. A piece of space the size of a star or a planet would probably be a non-homogeneous sample, but if you measured off a portion of the universe that was a billion light-years on a side, you would probably get the same mix of galaxies and space regardless of where you took your sample.



Isotropic means that a sample looks much the same in every direction. In recent years, clusters and voids have been found in samples that have been hundreds of millions of light-years on a side, and galaxies, clusters, and superclusters have been found in equal numbers in all parts of the universe.

So, on a large scale, is our universe isotropic and homogenous? If we mapped a large enough wedge out of our universe and we placed ourselves at the point of the wedge, would we observe much the same kind of map of structures and voids, wherever the sample was taken?